



Human footprints on Earth as seen by NASA scientists



Module Overview

This module draws upon NASA images and research to introduce students to the various ways humans interact with Earth's diverse environments. Many human activities are clearly visible from space through satellite imagery. Remotely sensed images help people understand Earth as the home for humanity. We can learn a great deal about physical and human processes by analyzing remotely sensed images.

The human footprint on Earth's surface is barely perceptible in some areas, whereas it is very intense and highly noticeable in others. We cannot detect the effects of some environmental changes without the use of powerful technologies, and some remain invisible even on photography and satellite imagery. For example, some forms of air pollution cannot be seen even though they affect people's health. Interpretation of imagery relies heavily on visual cues but excludes other sensory information such as sounds and odors.

The investigations in this module begin with an examination of the spatial and environmental aspects of a shopping mall in Huntsville, Alabama. Next, comes a study of Atlanta's urban heat island and the consequences of urban deforestation. Then students are asked to consider significant environmental changes in different parts of the world. Deforestation in Rondonia, Brazil, provides a case study of a major environmental change. The investigations in the module proceed from the local to the global scale. This sequence allows students to apply what they learn to environmental change at different scales.

Investigation 1: Let's go to the mall

This investigation examines the significance of the location of shopping malls. Huntsville, Alabama, is used as an example to illustrate that different human activities have different location requirements. Studying malls from a spatial perspective demonstrates the usefulness of geography in daily life and offers opportunities for direct observation and fieldwork.

Investigation 2: What's hot at the mall?

This investigation examines how shopping malls change the natural environment. Studying NASA thermal images of a mall and its immediate surroundings introduces students to environmental changes related to urban deforestation and to the formation of urban heat islands. Studying malls from an environmental perspective also demonstrates the usefulness of geography in daily life and offers opportunities for direct observation and fieldwork.

Geography Standards

Places and Regions

- **Standard 4:** The physical and human characteristics of places

Human Systems

- **Standard 11:** The patterns and networks of economic interdependence on Earth's surface
- **Standard 12:** The processes, patterns, and functions of human settlement

Environment and Society

- **Standard 14:** How human actions modify the physical environment
- **Standard 15:** How physical systems affect human systems

Uses of Geography

- **Standard 18:** How to apply geography to interpret the present and plan for the future

Science Standards

Unifying Concepts and Processes

- Systems, order, and organization

Science in Personal and Social Perspectives

- Populations, resources, and environments
- Risks and benefits

Investigation 3: Why is the city hot?

This investigation examines the formation of urban heat islands. NASA scientists are studying the urban heat island of Atlanta and other cities. This investigation uses thermal images and research by NASA scientists to examine causes of environmental change in Atlanta and actions that might be taken to reduce the harmful effects of that change.

Investigation 4: Where in the world are major environmental changes?

This investigation introduces students to significant environmental changes occurring in different parts of the world. The investigation uses NASA satellite images of Brazil to illustrate deforestation as an example of environmental change. Students learn that satellite images provide useful information for interpreting, understanding, and predicting environmental change.

Connection to the Curriculum

Investigations in the module require students to locate places and regions on maps, make simple maps, interpret maps and satellite images, and obtain and use information from atlases. Local community studies are incorporated through consideration of the expansion of urban areas and transportation systems in the students' home areas. The module emphasizes the nature and consequences of human–environment interactions and examines changes in ecosystems and in how societies organize themselves in space. The module is linked to earth science through physical geography and to history and social studies through the study of changes in urban areas and local communities. In addition, students learn about applying remote-sensing technology to environmental issues.

Time

Investigation 1: Two 45-minute sessions
Investigation 2: Two 45-minute sessions
Investigation 3: Three 45-minute sessions
Investigation 4: Four 45-minute sessions

Module Assessment

The successful completion of the Logs should provide a means to assess student learning. A more comprehensive assessment could use the learner objectives to shape assessment activities.

Mathematics Standards*Geometry*

- Use visualization, spatial reasoning, and geometric modeling to solve problems

Measurement

- Apply appropriate techniques, tools, and formulas to determine measurements

Representation

- Use representation to model and interpret physical, social, and mathematical phenomena

Technological Literacy Standards*Nature of Technology*

- The characteristics and scope of technology

Technology and Society

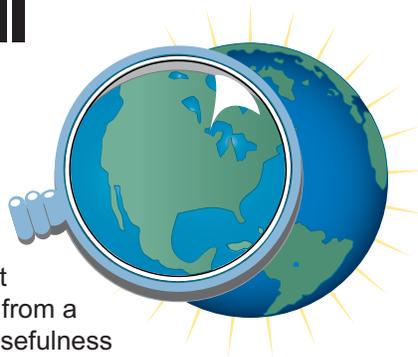
- The cultural, social, economic, and political effects of technology
- The effects of technology on the environment



Let's go to the mall

Investigation Overview

This investigation examines the significance of the location of shopping malls. Huntsville, Alabama, is used as an example to illustrate that different human activities have different location requirements. Studying malls from a spatial perspective demonstrates the usefulness of geography in daily life and offers opportunities for direct observation and fieldwork.



Time required: Two 45-minute sessions

Materials/Resources

Briefing and Logs 1, 2, 3 and 4 (one copy of each per student)
Newsprint
Overhead transparencies
Markers

Content Preview

Studying malls helps students to develop a spatial perspective. Students use this spatial perspective to explore how malls and other commercial land uses relate to the location of residences, roads, and local traffic. Studying malls helps students understand economic patterns in the landscape.

Checklist of Classroom Procedures

Beginning the Investigation

1. Have students develop a list of different topics that they think NASA scientists are studying. Share the list with the class. Discuss the topics presented and have students identify which topics are local issues and which may be global issues.
2. Using this discussion as a starting point, explain to students that NASA scientists study many different topics and use photos and data gathered by airplanes as well as images and data gathered by satellites. Sometimes the topics that NASA scientists study are very important in local communities. In all locations, it is important for us to know how human activities affect the use of land.
3. Open the discussion of the impact of shopping malls on the landscape by asking students to write some reasons why it is important to have convenient places to shop. List the reasons on the board or overhead transparency. The ideas may include:
 - People have diverse needs and wants that are filled by buying goods and services.
 - People like to go to nearby places to buy everyday items.
 - It saves time to shop near one's home or work.
 - Places to shop should be easy to get to and easy to use.
 - People like to keep travel costs low.

Geography Standards

Standard 11: Human Systems

The patterns and networks of economic interdependence on Earth's surface

- Analyze and evaluate issues related to the spatial distribution of economic activities.

Geography Skills

Skill Set 2: Acquiring Geographic Information

- Use maps to collect and compile geographic information.

Skill Set 3: Organizing Geographic Information

- Prepare various forms of maps as a means of organizing geographic information.

Skills Set 4: Analyzing Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.

4. Ask students to identify some advantages and disadvantages of walking versus driving to shopping places. Discuss the differences between walking to shopping places and driving to shopping places. Discussion may include:
 - Walk-to places may have few parking spaces.
 - Drive-to places may have many parking spaces.
 - Having a car influences where people go to shop.
 - Places farther away from home are more accessible with a car.

Developing the Investigation

5. Ask students to read the **Briefing** on malls and distribute **Log 1**. Small groups may discuss the questions and complete the rankings of land uses most important for malls to be near. This Log will help students think about why activities and facilities are located in different places. Group responses may be displayed on newsprint, on overhead transparencies, or on the chalkboard.
6. Distribute **Log 2**. Ask students to complete the activity ranking the features that are most important and least important to the location of community facilities (sports stadium, airport, high school, fire station, and hospital). Discuss the results.
7. Distribute **Log 3** containing the Huntsville image and ask students to identify the feature that is most likely a mall and give some reasons for their answers. Ask them to speculate about other features on the image and to try to identify what they are. For example, they may mention major highways, residential areas, strip malls, movie theaters, and research parks. Have students complete the questions on **Log 3**.
8. Once students have identified the shopping mall (Madison Square Mall) and completed **Log 3**, ask them to list and rank the features which they believe were important in locating the mall. They should offer reasons for their answers. For example, they may say that land was available or that it is important for the mall to be near the intersection of major highways, near residential areas, or close to other businesses that create customer traffic.

Concluding the Investigation

9. Distribute the Huntsville image with the features labeled and ask them to study it, complete **Log 4**, and share the results with the class.

Background

Malls are prominent cultural landscape features and are a part of everyday life for most students. Studying mall locations helps students understand economic patterns in their communities and applies geography to daily life.

Malls use a lot of land and are easily seen on aerial photos and satellite images. Factories, large school campuses, and office parks may look similar to shopping malls on remotely sensed images. Distinguishing between different land uses provides opportunities for critical thinking.

A mall's location and parking spaces display our dependence on cars. Malls are usually located near major highways, have large parking lots, are close to other shopping areas, and have many retail stores under one roof. People drive to malls because they want convenient and accessible places to shop and socialize.

NASA Image

NASA collected the Huntsville image used in this investigation in 1994 with ATLAS (Airborne Thermal/Visible Land Application Sensor), which sees in 15 colors, aboard a Lear 23 jet. The ATLAS imager scans and maps patterns in urban areas and records temperatures. ATLAS is the same basic instrument as the one on board Galileo, the unmanned NASA spacecraft now orbiting Jupiter. The images of Huntsville show residences, roads, and different commercial activities in urban areas.

Evaluation

Log 1

Additional features may include g) a public bus system and h) being near a large population center.

As the three most important features for a mall to be near, students may select a, c, and h. They may say that these features make it easy for a large number of people to get to the mall. Students may select other features and offer reasons for those choices.

As the three least important features for a mall to be near, students may select b, d, and e. They may say that these features may cause conflicts with the traffic coming in and out of the mall. Students may select other features and offer reasons for those choices.

Log 2

An example is provided in the Log.

Log 3

Examples of human-built features in the image include roads, parking lots, houses, and other buildings that could be factories or research parks.

Natural features in the image are very limited. The best examples are tree-covered and grassy areas.

Log 4

An example is provided in the Log.



Module 3, Investigation 1: Briefing

Let's go to the mall

Background

This investigation examines why malls are located where they are.

You may have noticed that there are different types of malls. For example, strip malls may have several stores lined along a busy street or may be arranged around a shared parking area. Outlet malls usually have brand name discount stores in separate buildings with ample parking. Other malls have many stores under one roof surrounded by large parking lots. Often these malls are multilevel and very large. Over time malls have increased in size and in the range of goods and activities they offer. In addition to numerous retail stores, they may have food courts, movie theaters, skating rinks, video arcades, and other forms of entertainment. This type of large mall is the topic of this investigation.

Malls use a lot of land and stand out on the landscape. They are large enough to appear on aerial photos and satellite images. Malls affect other places in a community and encourage dependence on automobiles. Wherever malls are built, vegetation and wildlife habitat are lost.

Shopping malls are found in large and small communities and are a part of everyday life for most people in the United States. Studying mall locations helps us understand patterns of economic activity in our communities and applies ideas about geography to daily life.

Objectives

In this investigation you will

- describe why malls are located in some places and not other places, and
- explain why NASA scientists are interested in studying malls.

Procedures for the Investigation

You will consider different aspects of the locations of shopping malls and examine images gathered by NASA showing an area in Huntsville, Alabama. Complete Logs distributed by your teacher.



Module 3, Investigation 1: Log 1

Let's go to the mall

Assume that you want to build a large shopping mall in your community. You will need a big parcel of relatively flat land. If you did field work in the area, you might identify several suitable parcels of land. To aid you in making a site selection, here is a list of features which may be important to the location of a mall. Add any features you think are missing.

- a. A four-lane road or interstate highway
- b. A manufacturing area
- c. A residential neighborhood
- d. A neighborhood shopping area
- e. An elementary school
- f. A sewage treatment plant
- g. _____
- h. _____

Select from the list the three most important and the three least important features for the mall to be near. Give reasons for your answers.

Most important and why?

- 1. _____

- 2. _____

- 3. _____

Least important and why?

- 1. _____

- 2. _____

- 3. _____



Module 3, Investigation 1: Log 2

Let's go to the mall

There are good reasons why things end up in different locations. Now that you have considered the best site for a mall, you may examine other facilities in our communities. In this Investigation Log you consider locations of certain **features** and various community **facilities**. What are the consequences of different land uses being near each other? For example, what are some possible positive and negative relationships of a stadium being near a residential neighborhood? A sample set of answers is provided for **stadium**.

| Community Facilities | Features | | | | | |
|----------------------|-----------------------|--------------------------------------|--------------------|---------------------------------|-------------------|---------------------|
| | Highway | Manufacturing | Shopping | Neighborhood | Elementary School | Sewage Plant |
| Stadium | Easy to get to events | Possible noise and competing traffic | Fans like shopping | Stadium too noisy for residents | Too much traffic | Odors distract fans |
| Airport | | | | | | |
| High School | | | | | | |
| Fire Station | | | | | | |
| Hospital | | | | | | |



Module 3, Investigation 1: Log 3

Let's go to the mall

Figure 1: Huntsville, Alabama by day



Source: http://science.msfc.nasa.gov/newhome/headlines/atlanta/hsv_IR.gif

Examine the Huntsville image and identify which feature is most likely a shopping mall. Using the major roads for orientation and assuming that the top of the image is north, describe the location of the mall. Give reasons to support your choice.

Continue to examine the image of Huntsville and list what types of human-built features are in the vicinity of the mall.

Human-Built Features

1. _____
2. _____
3. _____
4. _____

Natural Features

What are some natural features that you can identify on the image?



Module 3, Investigation 1: Log 4

Let's go to the mall

Now examine the Huntsville image with the land uses labeled (Figure 2). For each of the uses listed below identify **one advantage** and **one disadvantage** of being near the mall. A sample set of answers is provided for the movie theater.

| | Advantage | Disadvantage |
|--------------------|--|---|
| Movie theater | People shopping can easily go see a movie. | The mall and the movie theater compete for parking. |
| Auto dealership | | |
| Residential area | | |
| Strip mall | | |
| Manufacturing area | | |
| Restaurants | | |
| Bank | | |

Discussion Questions

1. According to people in the Huntsville area, the Madison Square Mall was built before all of the other commercial facilities shown in the image. Why would restaurants, a bank, a hotel, movie theater, and car dealers move near a shopping mall? _____

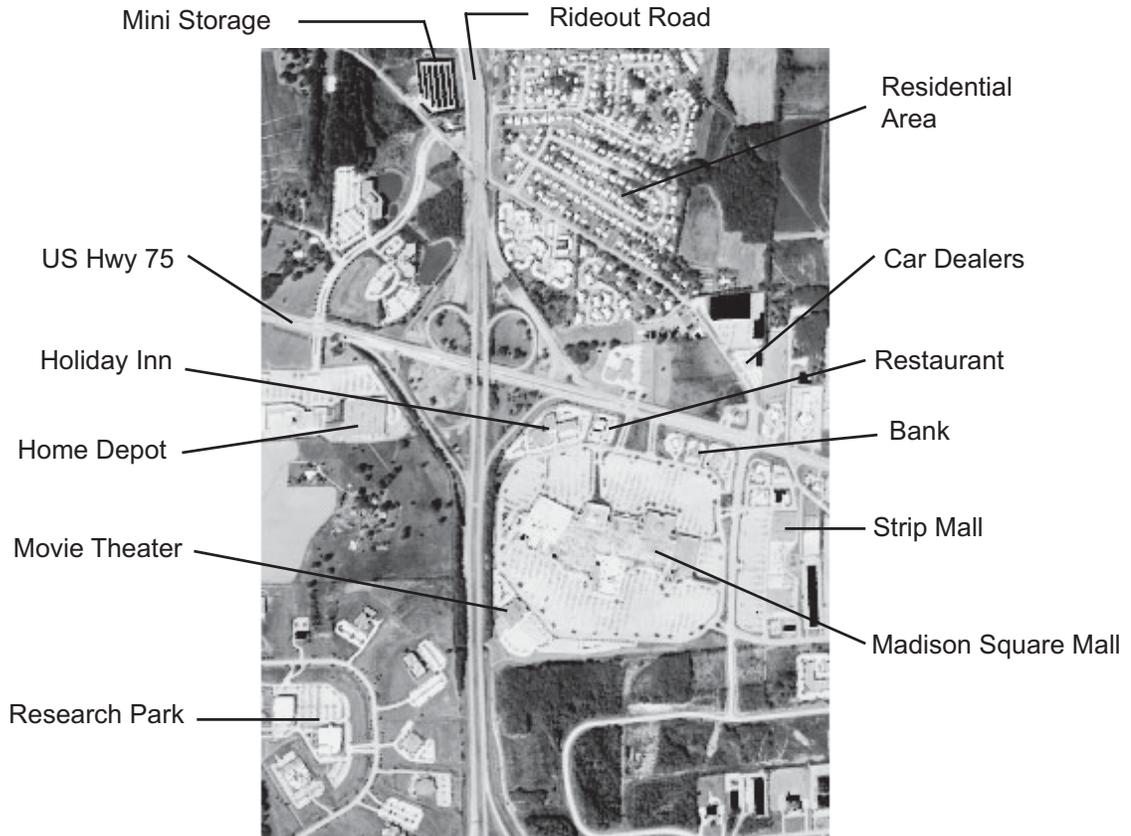
2. Would you want a new mall built across the street from your home? Why or why not?



Module 3, Investigation 1: Log 4

Let's go to the mall

Figure 2: Madison Square Mall and Surroundings



References

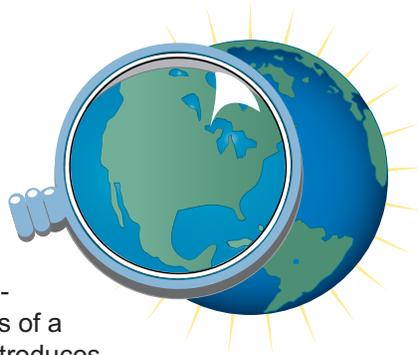
Geography for Life: National Geography Standards 1994

http://science.msfc.nasa.gov/newhome/headlines/essd08may97_1.htm

Background on Huntsville and features of the Madison Square Mall vicinity was provided by Blaine Adams, geography graduate student at Virginia Tech and native of Huntsville, Alabama



What's hot at the mall?



Investigation Overview

This investigation examines how shopping malls change natural environments. Studying NASA thermal images of a mall and its immediate surroundings introduces students to urban deforestation and to the formation of urban heat islands. Studying malls from an environmental perspective demonstrates the usefulness of geography in daily life and offers opportunities for direct observation and fieldwork.

Time required: Two 45-minute sessions

Materials/Resources

- Briefings 1 and 2 and Logs 1, 2, and 3 (one copy per student)
- Figures 1 and 2
- Color transparency or color copies of Figure 3 (student materials p. 7)
- World Atlas
- Political map of the United States
- Road atlas of the United States
- Blank sheets of paper
- Overhead transparencies
- Markers

Content Preview

It is important for us to know how human activities influence the environment. Scientists use aerial photos, satellite images, maps, census data, and other information to examine land use changes and the impact they have on the environment. Shopping malls and their surrounding areas provide excellent examples of temperature changes produced when trees and vegetation are replaced by buildings and pavement. There are intended and unintended environmental consequences when a shopping mall is constructed.

Classroom Procedures

Beginning the Investigation

If you have completed Investigation 1 in this module, proceed directly to 5 in **Developing the Investigation**.

1. Have students develop a list of topics that they think NASA scientists are studying. Share the list with the class. Discuss the topics and have students identify which topics are local issues and which are global issues.
2. Using the class discussion as a starting point, explain to students that NASA scientists study many topics and use photos and data gathered by airplanes as well as images and data gathered by satellites. Sometimes the topics that the NASA scientists study are very important to

Geography Standards

Standard 14: Environment and Society

How human actions modify the physical environment

- Analyze the environmental consequences of humans changing the physical environment.

Geography Skills

Skill Set 3: Organizing Geographic Information

- Prepare various forms of diagrams, tables, and charts to organize and display geographic information.

Skill Set 4: Analyzing Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.

our local communities. One example is studying how land heats up when forest cover and other vegetation is removed and replaced by buildings and roads.

- Open the discussion of shopping malls by asking students to write down some reasons why it is important to have convenient places to shop. List the reasons on the board or overhead transparency.

Reasons may include:

- People have diverse needs and wants that are filled by buying goods and services.
- People like to go to nearby places to buy everyday items.
- It saves time to shop near one's home or work.
- Places to shop should be easy to get to and easy to use.
- People like to save money getting from place to place.

Developing the Investigation

- Provide a copy of **Figure 1**, the Huntsville day image, and ask students to identify the feature that is most likely a mall and to give some reasons for their answers. Ask them to speculate about other features on the image and to try to identify what they are. For example, they may mention forests, open land, major highways, residential areas, strip malls, movie theaters, and industrial areas.
- Distribute **Briefing 1** and have students read the Background, Objectives, and Procedures.
- Distribute **Log 1** and ask students to consider how the construction of a mall affects the surrounding environment. For example, malls sometimes replace ecosystems such as forests, wetlands, or open grasslands. These ecosystems provide habitats for wildlife and play an important role in pollution control. Have students identify what will happen to the environmental features listed in the Log when a mall is built.
- Distribute **Log 2** and **Figure 2**. Ask students to examine the daytime thermal image of Huntsville. In the thermal image warmer temperatures are represented by lighter shades of gray & white; the darker shades show cooler temperatures. Students should answer the questions in the Log.

Concluding the Investigation

- Have students read the NASA research in **Briefing 2**. Distribute **Log 3**. Ask students to examine the thermal images of the tree in a parking lot and notice differences in the night and day temperatures around the tree.

Provide large sheets of paper and ask students to develop sketch maps (as described in **Log 3**) that show arrangements of trees that would more effectively cool a mall parking area.

As a final activity, if you have not already done this, have students discuss or write about the following questions:

- What are some of the major environmental impacts caused by a shopping mall?
- Would you want a new mall to be built across the street from your house? Why or why not?

Background

NASA uses an ATLAS imager to gather thermal images of parts of Earth's surface. These images help scientists understand how the heat captured and then released by a city's buildings and pavement coupled with the loss of trees and other vegetation affect local weather, air quality, and air and surface temperatures.

It is important for us to know how human activities influence the environment. Scientists use aerial photos, satellite images, maps, census data, and other information to examine land use changes and the impact they have on the environment. For example, aerial photos and thermal measurements of an area in Huntsville, Alabama, are used in this investigation to study the effect of urbanization on surface temperatures. Interestingly, shopping malls and their surrounding areas provide excellent examples of temperature changes produced when trees and vegetation are replaced by buildings and pavement.

NASA collected the Huntsville images used in this investigation with ATLAS (Airborne Thermal/Visible Land Application Sensor), which sees in 15 colors, aboard a Lear 23 jet. The ATLAS imager scans and maps heat patterns in urban areas. ATLAS is the same basic instrument as the one on board Galileo, the unmanned NASA spacecraft now orbiting Jupiter.

Studying malls helps students to develop an ecological perspective by considering the environmental consequences of land use change, in this case the removal of vegetative cover and natural habitat. There are intended and unintended environmental consequences when a shopping mall is constructed. Intended consequences include construction of roads and clearance of land to provide parking. Unintended consequences include creation of traffic problems, absorption and consequent radiation of heat after sundown by large areas of pavement, and an increase in water pollution from oil and salt runoff from parking lots.

Evaluation

Log 1

1. An example is provided in the Log.
2. Trees are cut down and other vegetation removed. A small amount of replacement vegetation is planted in landscaped areas around the mall.
3. Some animals lose their habitats. They must move to other forested areas.
4. Moving Earth material will alter the way that water flows. More sediment may enter streams due to erosion of disturbed land.
5. Temperatures of air and land will sometimes increase due to heat retained and then released by pavement and buildings. This will warm the area.

Log 2

1. Madison Square Mall parking lot
2. Areas of tree cover in lower right of the image. Other tree-covered areas appear at top left and right of the image.
3. The Sun's rays cause paved areas and buildings to heat up. Trees and other vegetation help cool areas around the mall.
4. Cool spots are indicated by the dark dots scattered around the mall parking lot. Trees are the cause of the dark dots and indicate cool spots.
5. Parking areas around malls could be made cooler by planting more trees.



Module 3, Investigation 2: Briefing 1

What's hot at the mall?

Background

This investigation examines how shopping malls change natural environments.

NASA scientists have been studying how hot it gets around shopping malls. Wherever malls are built trees and wildlife habitat are lost. Malls use a lot of land, stand out on the landscape, and are visible on aerial photos and satellite images.

Vegetation shades areas, preventing a build up of heat. Trees absorb and use the Sun's energy for photosynthesis. The loss of vegetation in built-up and paved areas causes the formation of hot spots. Heat builds up during the day because the Sun's energy is retained by buildings and pavement. This causes surface temperatures and the surrounding air temperature to rise. Much of this stored-up heat is released at night.

On a hot summer day we may feel a blast of heat when we walk from an air-conditioned mall across an asphalt parking lot to our car. The heat rises from the pavement to meet us and warms us all the way across the lot. While we shopped, our car absorbed the Sun's rays and heated up. During the summer, temperatures in parking lots are as high as 49°C (120°F). When you add up all the heat from parking lots, buildings, cars, and roads, and remove the trees that might soak up the heat and keep things cool, it is no wonder that temperatures rise in built-up areas.

Objectives

In this investigation you will

- identify topics that NASA scientists study;
- explain why NASA scientists are interested in studying malls;
- correctly identify a mall on the Huntsville, Alabama, thermal image;
- distinguish between hot and cool areas on thermal images; and
- explain some of the environmental consequences of constructing a shopping mall.

Procedures for the Investigation

You will consider environmental changes caused by shopping malls by examining thermal images gathered by NASA showing an area in Huntsville, Alabama. A thermal image shows differences in temperature on Earth's surface. You may be working alone or in groups to complete Logs distributed by your teacher.

References

Geography for Life: National Geography Standards 1994

http://science.msfc.nasa.gov/newhome/headlines/essd08may97_1.htm

Background on Huntsville and features of the Madison Square Mall vicinity was provided by Blaine Adams, geography graduate student at Virginia Tech and native of Huntsville, Alabama



Module 3, Investigation 2: Log 1

What's hot at the mall?

The construction of a mall affects the surrounding environment. Malls sometimes replace ecosystems such as forests, wetlands, or open grasslands. These ecosystems provide habitats for wildlife and play an important role in pollution control.

Identify what happens to the following environmental features when a mall is built. An example is provided for #1.

1. Land and soils

A mall will cover a lot of soil with buildings and pavement. Rainwater cannot soak into the pavement and may run off to nearby land, causing erosion.

2. Forest and vegetation

3. Wildlife habitats

4. Streams and drainage patterns

5. Temperature of air and ground



Module 3, Investigation 2: Figure 1

What's hot at the mall?



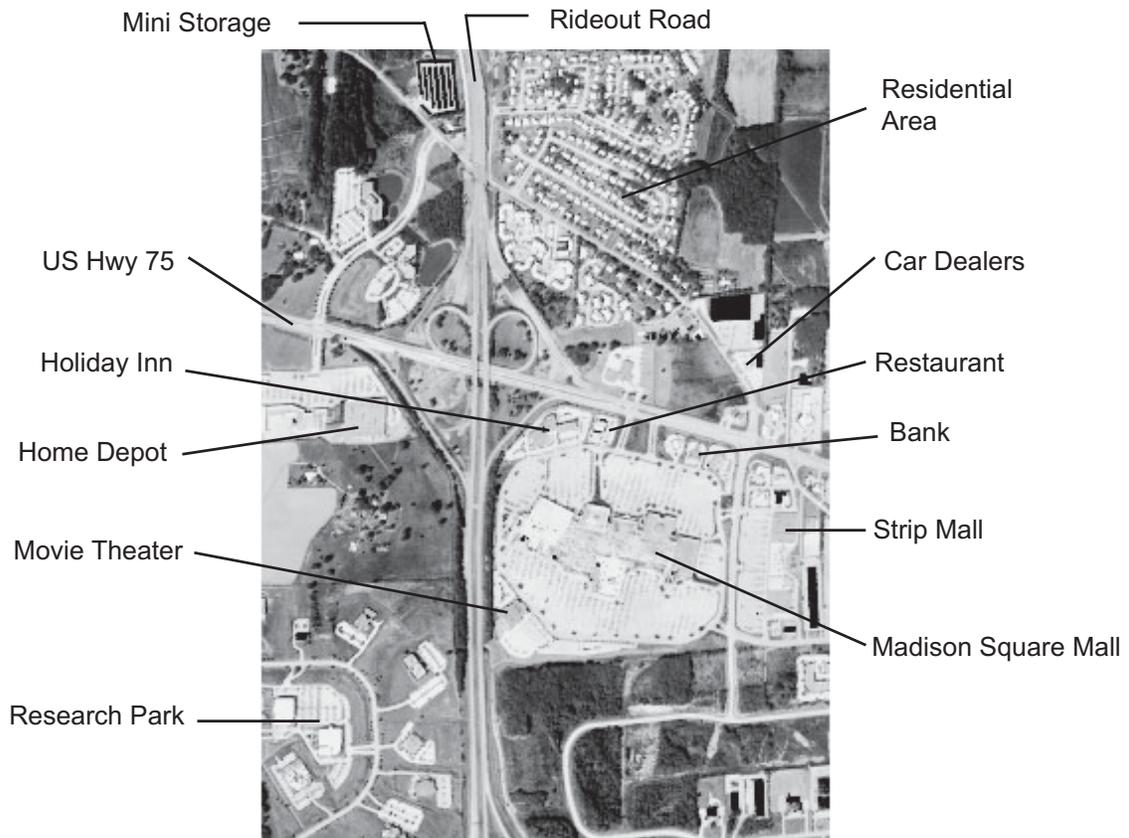
Source: http://science.msfc.nasa.gov/newhome/headlines/atlanta/hsv_IR.gif



Module 3, Investigation 2: Figure 2

What's hot at the mall?

Huntsville, Alabama, by day





Module 3, Investigation 2: Log 2

What's hot at the mall?

Now that you have considered some of the environmental effects of malls, examine the daytime thermal image of Huntsville. In the thermal image, warmer temperatures are represented by lighter shades of gray and white, and cooler temperatures by darker shades. Use Figures 1 and 2 to answer the following questions.

1. What is the largest warm feature on the image?

2. What is the largest cool feature on the image?

3. Why are some areas warmer than other areas? For example, why is the shopping mall parking lot warmer than the trees and grassy areas in the highway cloverleaf?

4. Can you find any cool spots in the mall parking area? What causes those cool spots?

5. Do you have any suggestions for making the parking areas cooler during the day?



Module 3, Investigation 2: Briefing 2

What's hot at the mall?

It is important to understand that just as much sunlight falls on cities as on woodlands of the same size. The difference is in how urban materials react to solar energy. Asphalt in parking lots and on rooftops, in particular, soaks up heat and reradiates it as thermal infrared radiation.

On the other hand, water absorbs a large amount of heat before its temperature rises, and it takes a long time to release it. That means that trees, which have a large water content and release water into the atmosphere to keep cool, absorb a lot of the incoming heat and release it over a longer period of time.

The temperature differences shown in the image are related to how materials absorb and release heat. Asphalt absorbs heat from the Sun and quickly releases it as heat radiation. Temperatures in the parking lot during summer are as high as 48.9°C (120°F) during the day, while tree islands in the lot are only 31.7°C (89°F)—a difference of 17.2°C (31°F)! At the same time nearby wooded areas are as low as 29.4°C (85°F). High daytime temperatures result in the parking lot cooling to only 23.9°C (75°F) at night. The tree islands and the woods are much cooler at 17.2°C (63°F). Even grassy areas near the woods are hotter than the woods because the meadow has less vegetation and shade.

Edited excerpt from *Research at NASA's Global Hydrology and Climate Center*
http://science.msfc.nasa.gov/newhome/headlines/essd08may97_1.htm



Module 3, Investigation 2: Log 3

What's hot at the mall?

Now that you have considered how to interpret a thermal image, read the NASA research handout Briefing 2 provided by your teacher.

After reading it, look at Figure 3, the day and night thermal images of the individual tree in a parking lot. Notice that the tree produces a shaded, cool area. In the night image, notice that the tree's leaves become so cool that they become nearly invisible.

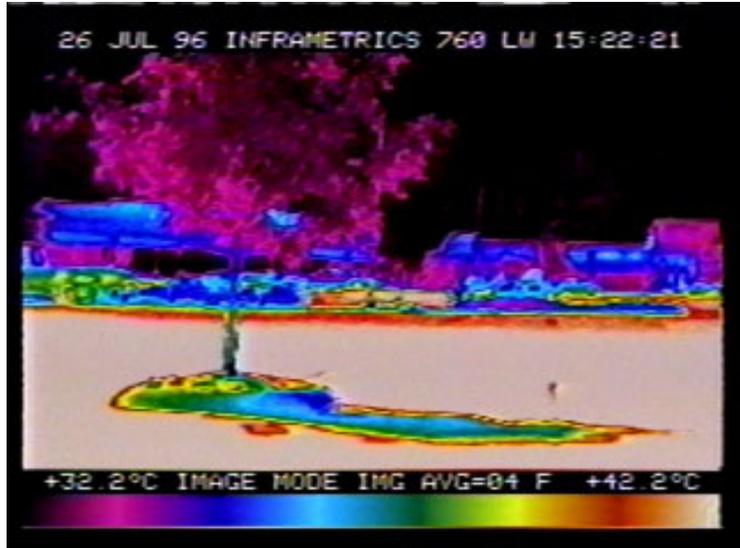
Now that you know about the effects that trees have on surface temperatures, consider how the temperatures of areas around a mall might be reduced if more trees were planted.

Using the Huntsville Madison Square Mall as a model, develop a sketch map of the ideal placement of trees in the parking areas. Use a large piece of paper so that you have plenty of space to draw your map. Keep in mind some of the disadvantages of having a large number of trees and vegetation around a shopping mall. For example, trees may reduce visibility, attract birds and other animals, and contribute to the loss of valuable parking spaces. When you share your map with others, be ready to explain why you located trees in certain sites and not in others.

Discussion Question

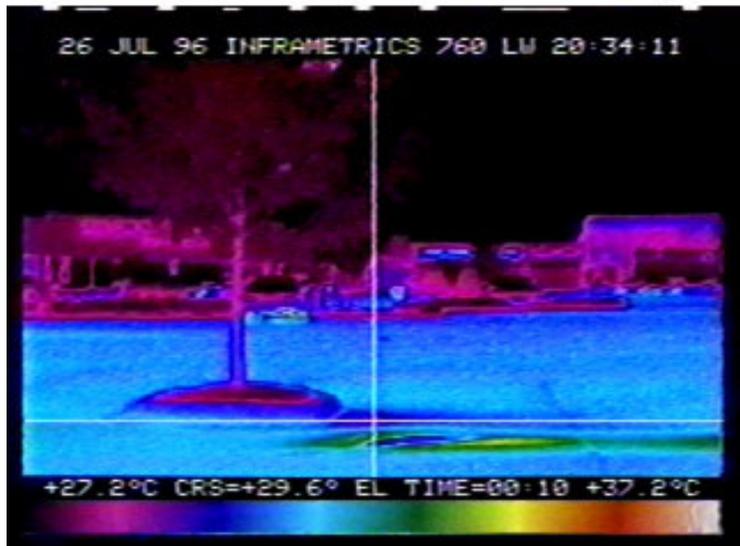
How would a new mall built across the street from your house affect your local environment? Write a brief answer on this sheet.

Figure 3: A tree in a parking lot



Day

Night



The color images are found at this NASA site:

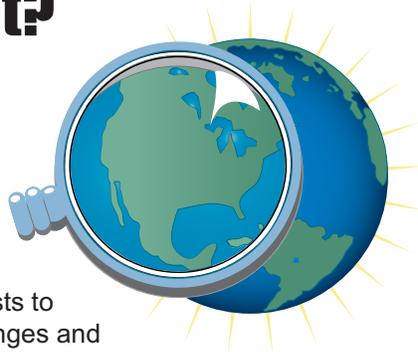
http://science.msfc.nasa.gov/newhome/headlines/essd08may97_1.htm



Why is the city hot?

Investigation Overview

This investigation examines the formation of urban heat islands. NASA scientists are studying the urban heat island in Atlanta and in other cities. This investigation draws on thermal images and research by NASA scientists to examine causes of environmental changes and actions that might be taken to reduce the harmful effects of those changes.



Time required: Three 45-minute sessions

Material/Resources

Briefing and Logs 1 and 2 (one copy of each per student)

Color transparencies of:

Figure 1: Land use 1973

Figure 2: Land use 1987

Figure 3: Land use 1997

Figure 4: Sketch of an urban heat-island profile

Color photocopies of:

Figure 5: Atlanta, day and night (class set or one per student group)

World atlases

Outline maps of the United States

Road atlas of the United States

Overhead transparencies

Content Preview

Urban deforestation and urban sprawl lead to the formation of heat islands, areas of higher than normal temperature. Buildings and roads absorb more heat than trees and grass, causing a buildup of heat. Vegetation and trees help keep a city cool.

Classroom Procedures

Beginning the Investigation

1. Have students develop a list of different topics that NASA scientists are studying. Share the list with the class. Discuss the topics presented and have students identify which of their topics are local issues and which are global issues.
2. Explain to students that NASA scientists are studying land use change in urban areas to find out what happens when forests and vegetation are removed and replaced by buildings and roads. Scientists use aerial photos, satellite images, maps, census data, and other information to examine urban expansion. For example, satellite images of Atlanta show how the city has expanded into farmland and woodlands. Scientists are measuring temperature and rainfall to see what kinds of changes are occurring and how they affect people living in urban areas. This activity introduces students to some of the research conducted by NASA scientists.

Geography Standards

Standard 12: Human Systems

The processes, patterns, and functions of human settlement

- Explain the causes and consequences of urbanization.

Standard 14: Environment and Society

How human actions modify the physical environment

- Analyze the environmental consequences of human changes of the physical environment.

Standard 18: The Uses of Geography

How to apply geography to interpret the present and predict the future.

- Analyze the interaction between physical and human systems.

Geography Skills

Skill Set 1: Asking Geographic Questions

- Identify geographic issues, define geographic problems, and pose geographic questions.

Skill Set 2: Acquiring Geographic Information

- Use maps to collect and compile geographic information.

Skill Set 4: Analyzing Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.
- Use statistics and other quantitative techniques to evaluate geographic information.

Skill Set 5: Answering Geographic Questions

- Make generalizations and assess their validity.

- Using a map of the United States have students locate Atlanta and identify the location by latitude and longitude (33°45'N, 84°23'W). Ask students to describe where Atlanta is in relation to their own community. Using the scale given on the map, estimate how far away Atlanta is and how long it would take to get there by automobile.
- Distribute these population data for Atlanta to illustrate its rapid growth:

1980—2,138,000
1998—3,589,000

Ask students to calculate the change in the number of people (1,451,000) and the percentage of population increase (67.9%).

Have students discuss population growth in their own community. Has population been expanding, staying the same, or declining? Why? What is the relationship between population growth and land use change? Have students give some specific examples. Examples may include land clearing for new roads, housing, and shopping areas.

- Use an overhead transparency of **Figure 1** to explain how to interpret land use in Atlanta. The color legend and map provide the information needed.

After presenting the 1973 map, show the 1973 and **Figure 2** 1987 maps simultaneously and ask students to identify changes that have occurred. Discuss reasons why the changes occurred, such as migration of people to Atlanta and the development of new businesses and roads. On the 1973 map, point out that development is concentrated in the central area of the city and along major roads. Historically, some development was also located along rivers for access to water and water transportation. Later development grew toward the airport, which was once on the outskirts of the city. Most of the growth since 1973 is related to the accessibility provided by transportation routes. Also, growth tended to occur near already built-up areas.
- Distribute **Log 1** containing the 1987 map divided into quadrants with an alphanumeric grid. Provide a brief explanation of quadrants and an alphanumeric grid system.

On **Log 1**, students predict where expansion took place between 1987 and 1997 (**Figure 3**) by identifying grid units where they believe that the expansion occurred. After completing the **Log**, use a road atlas of the United States to have students look at the road network and other features in the Atlanta region. Identify and describe the locations of the interstate highways in and around the city. (Examples: *Interstates 20, 85, and 75.*)

Developing the Investigation

- Show students **Figure 4**, and discuss how an urban heat island is measured. Sometimes remote-sensing devices on planes or satellites are used to detect temperature differences on Earth's surface. Urban heat islands are measured by observing temperatures in different locations across the city at different hours of the day and in different seasons. Temperatures are recorded for individual buildings, roads, parking lots, and vegetated areas. The high temperatures of individual features combine to raise the overall temperature of the city by 4.5-5.5°C (8-10°F). Areas that lose vegetation by adding concrete and asphalt structures experience the greatest increases in temperature.
- Distribute copies of **Figure 5**. Each image has an alphanumeric grid overlay to allow precise comparison of parts of the city. The focus is on the cooling process and how it affects the thermal appearance of the city. The city cools faster in areas with more vegetation and more slowly in areas with less vegetation. Individual features stand out more clearly on the night image. This is due to the greater variation in temperature across the city during the night. See the temperature scale on **Figure 4** for image interpretation.

Using a specially outfitted Lear Jet, NASA researchers collected thermal data for the Atlanta metro area. As shown in **Figure 5**, aircraft data are lined up with a larger image, taken from the orbiting Landsat 5 satellite. Notice how the buildings themselves help keep small areas cool, casting shadows across the pavement and walls of surrounding structures. Using the same color scale, you can see how much heat remains locked in the developed areas of the city at night.

9. **Log 2** asks students to compare the same pre-selected grid cells on both images. The objective is to have students see the differences in how clearly individual features such as major roads, the downtown area, or large housing subdivisions appear on the images. The night image provides finer detail and allows students to more readily identify features.

Concluding the Investigation

10. On **Log 2** ask students to create an equation that describes the relationships that lead to urban heat islands using the following terms and symbols:

| | |
|-------------------|--------------|
| urban heat island | ↑ (increase) |
| urban development | + (plus) |
| forests | = (equals) |
| | ↓ (decrease) |

Students should be able to develop the following equation:

$$\uparrow \text{ urban development} + \downarrow \text{ forests} = \text{urban heat island}$$

Have students write a sentence describing the relationships shown in the equation. A possible sentence might be: Increasing urban development and decreasing forests cause urban heat islands.

Background

Urban Sprawl, Urban Heat Islands, and Urban Deforestation

During the last few decades many cities in the south, southwest, and west experienced dramatic population growth. Atlanta, Georgia, was among the fastest growing cities in the United States during the '90s. The population of the city of Atlanta dropped from 495,039 in 1970 to 394,017 in 1990, but the suburban population in the surrounding 20 counties skyrocketed from 1.8 million to 3 million. The population of the city of Atlanta was 416,474 in 2000. The metropolitan area expanded so much that it is considered to have four central business districts rather than one. Rapid growth that spreads far from the center of a city and uses a lot of land is usually called urban sprawl. When heat builds up in a city it creates a hot spot within an area of cooler countryside. This hot spot is called an urban heat island.

Urban areas display higher temperatures than the more rural surrounding areas. The Sun's heat is absorbed by buildings and pavement, causing surface temperatures to rise. The gradual loss of vegetation and the increase of built-up and paved areas cause the formation of hot spots and urban heat islands. Stored-up heat is released at night and causes a dome of high temperature over the city compared to the cooler countryside. Heat islands or hot spots may be found even on the outskirts of an urban area such as at airports which have large areas of pavement.

NASA scientists are studying the relationship between tree removal and urban heat islands in Atlanta, Georgia. Scientists estimate that Atlanta's vegetation and tree cover have declined by 65 percent between 1973 and 1993. The area of tree loss equals 153,781 hectares. The trees were removed to make way for new urban growth.

Excerpt from NASA Research

<http://www.ghcc.msfc.nasa.gov/overview/urban.html>
Rapid population growth in the last 25 years (27 percent between 1970-80, and 33 percent in 1980-90) has made Atlanta one of the fastest growing metropolitan areas in the United States. This rapid growth has translated into an approximately 17 percent decline in forest land in the Atlanta metropolitan region between 1973 and 1992. Atlanta is also a model for what is in store for other cities, especially in developing nations where the industrial revolution is taking off and threatens large areas of forest or jungle. This enormous transformation of land from forest and agriculture to an urban landscape causes changes in land-atmosphere energy balance relationships.

The amount and location of urban forest are very important to how cool or how hot temperatures become in different parts of the city. Trees contain a lot of water and release that water into the atmosphere to keep themselves cool. Water absorbs a large amount of heat before showing significant rises in temperature. Also, trees absorb a lot of heat and release it slowly, which moderates temperatures of urban heat islands.

**Excerpt from a satellite's view of urban sprawl by
Richard L. Hill, *The Oregonian*, March 8, 2000**

Two geographers at the University of Maryland are using the nation's Landsat satellite system to analyze and compare the growth of cities. Jeffrey G. Masek and Francis E. Lindsay say that understanding how urban areas expand is important because half of the world's six billion people live in cities, an increase of more than one billion in the past 30 years. They say that a better understanding of urban growth patterns can answer such questions as how the spreading populations affect the landscape, how best to use limited space, and which social, economic, and environmental factors influence population expansion.

Sensor-loaded spacecraft are a valuable scientific tool in examining natural environments such as oceans, forests and mountains. Now, researchers are using the spacecraft to take a look at a less attractive aspect of our planet: urban sprawl.

The sensors aboard Landsat satellites are able to distinguish between vegetated and nonvegetated areas. With the aid of computers, the researchers can determine whether vegetation has changed during a period of time. "We basically say that urban growth is where we see vegetation at an earlier time and don't see it at the later time."

"We have data from these satellites going back for more than 20 years, so they provide us with a tremendous look at change," Lindsay said. "And that's going to be especially important because we can look at what change has happened in the past and make predictions about future growth in the world's urban centers."

Becoming a Cool Community

What can be done to reduce the negative consequences of an urban heat island? One step to reduce heat buildup is to increase all forms of vegetation in the city. Some scientists believe that a city should contain 40 percent park land, forest, and green spaces. (Atlanta has only 27 percent). This can be accomplished by limiting the number of trees cut when building, and planting trees wherever possible, planting shrubs and grasses in bare ground areas, and planting trees in median strips along roads and in parking lots. Other specific steps include planting more trees to shade sidewalks, parking lots, and buildings and replacing old roofs with new reflective roofing material.

Evaluation

Log 1

1. Change from 1973 to 1987

| Quadrant | # of changed units | Rank |
|-----------|--------------------|------|
| Northeast | 14 | High |
| Northwest | 13 | High |
| Southwest | 13 | High |
| Southeast | 10 | High |

4. Growth occurred along major highways, near the airport and expanded outward from the city center. Land near roads and developed areas tends to be more accessible to new development.

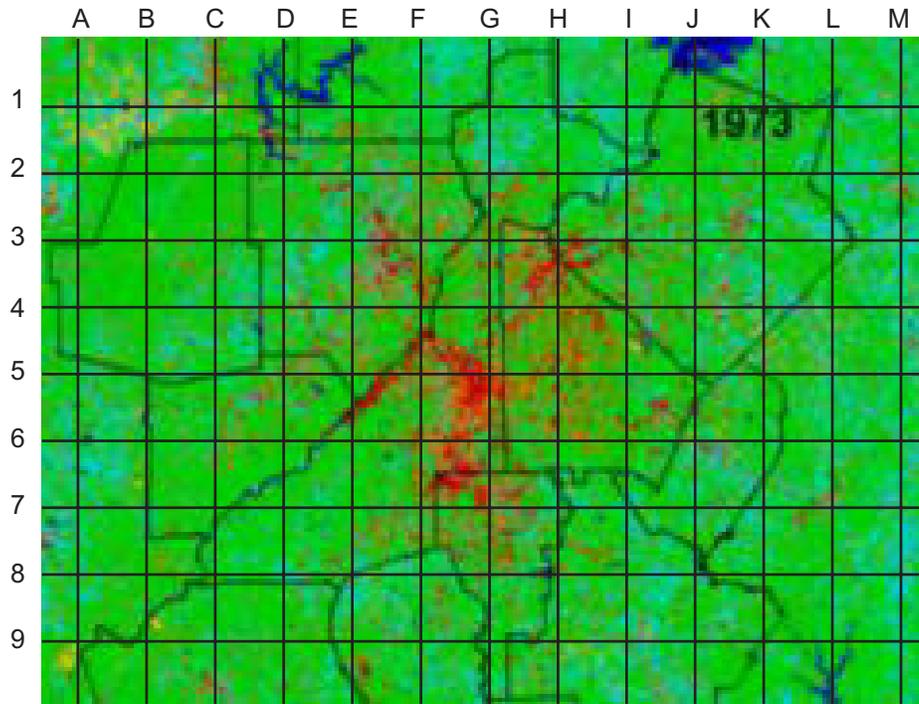
Log 2

1. The night image allows more precise identification of land uses.
2. During the day, roads, pavement, and buildings absorb much heat, and so on the day image they appear red. At night, as the temperature drops, the city becomes cooler and there is more color variation between buildings and roads and vegetation.
3. Pavement absorbs more heat than trees and cools at a slower rate, so roads appear orange or yellow on the image.
4. Areas along roads are often cooler because of the presence of trees and vegetation.

Resources

NASA, Global Hydrology and Climate Center, Huntsville, Alabama <http://www.ghcc.msfc.nasa.gov>
 NASA, Spacelink, an aeronautics and space resource for educators <http://spacelink.nasa.gov/>
 Science @NASA article: Atlanta's urban heat alters weather patterns http://science.nasa.gov/newhome/headlines/essd26apr99_1.htm
 American forests, Washington, D.C. (information on tree planting) <http://www.amfor.org>
 Environmental Protection Agency, Washington, D.C. (information on tree planting, reflective roofing and paving) <http://www.epa.gov><http://www.energystar.gov>
 Lawrence Berkeley National Laboratory, Berkeley, California (information on urban heat-island research, tree planting, reflective roofing and paving) <http://www.lbl.gov> and <http://EETD.LBL.gov>

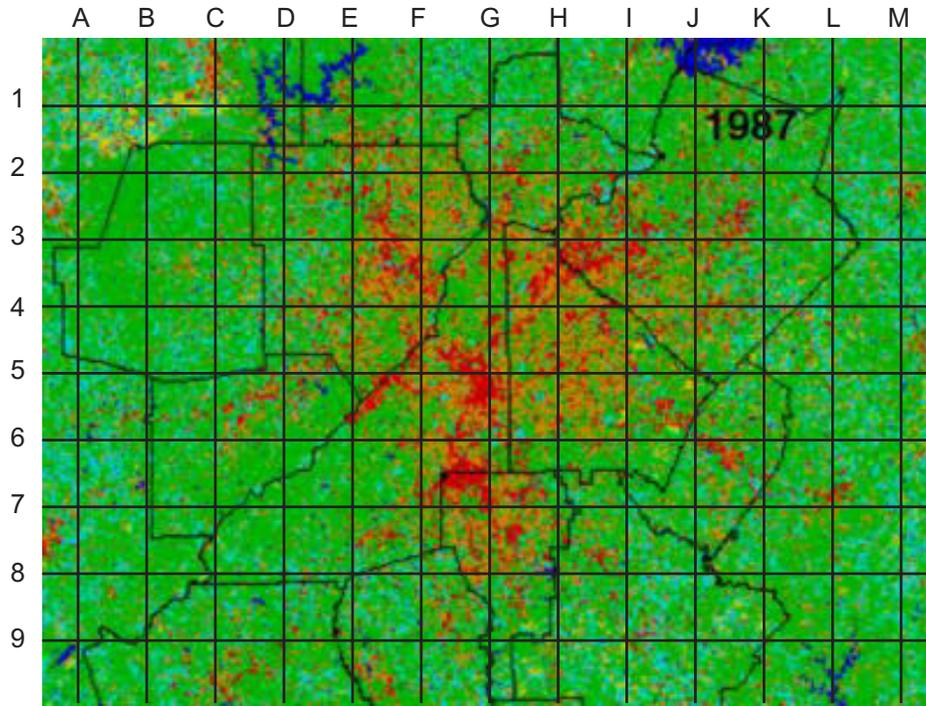
Figure 1: Land use 1973



Source: <http://svs.gsfc.nasa.gov/search/Keywords/Atlanta.html> — click on link for Atlanta Land Use.



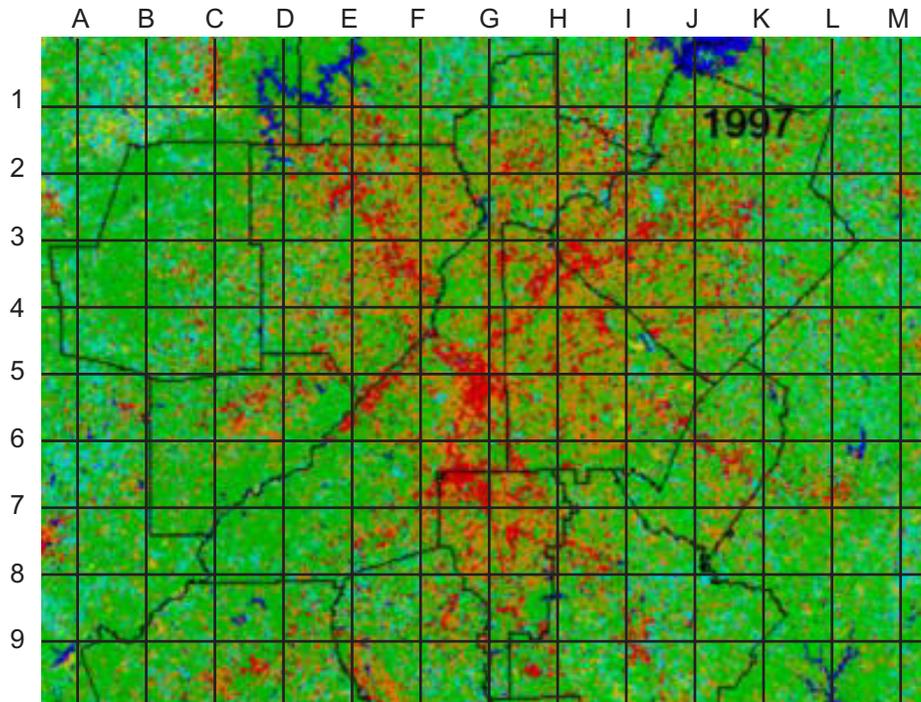
Figure 2: Land use 1987



Source: <http://svs.gsfc.nasa.gov/search/Keywords/Atlanta.html> — click on link for Atlanta Land Use.



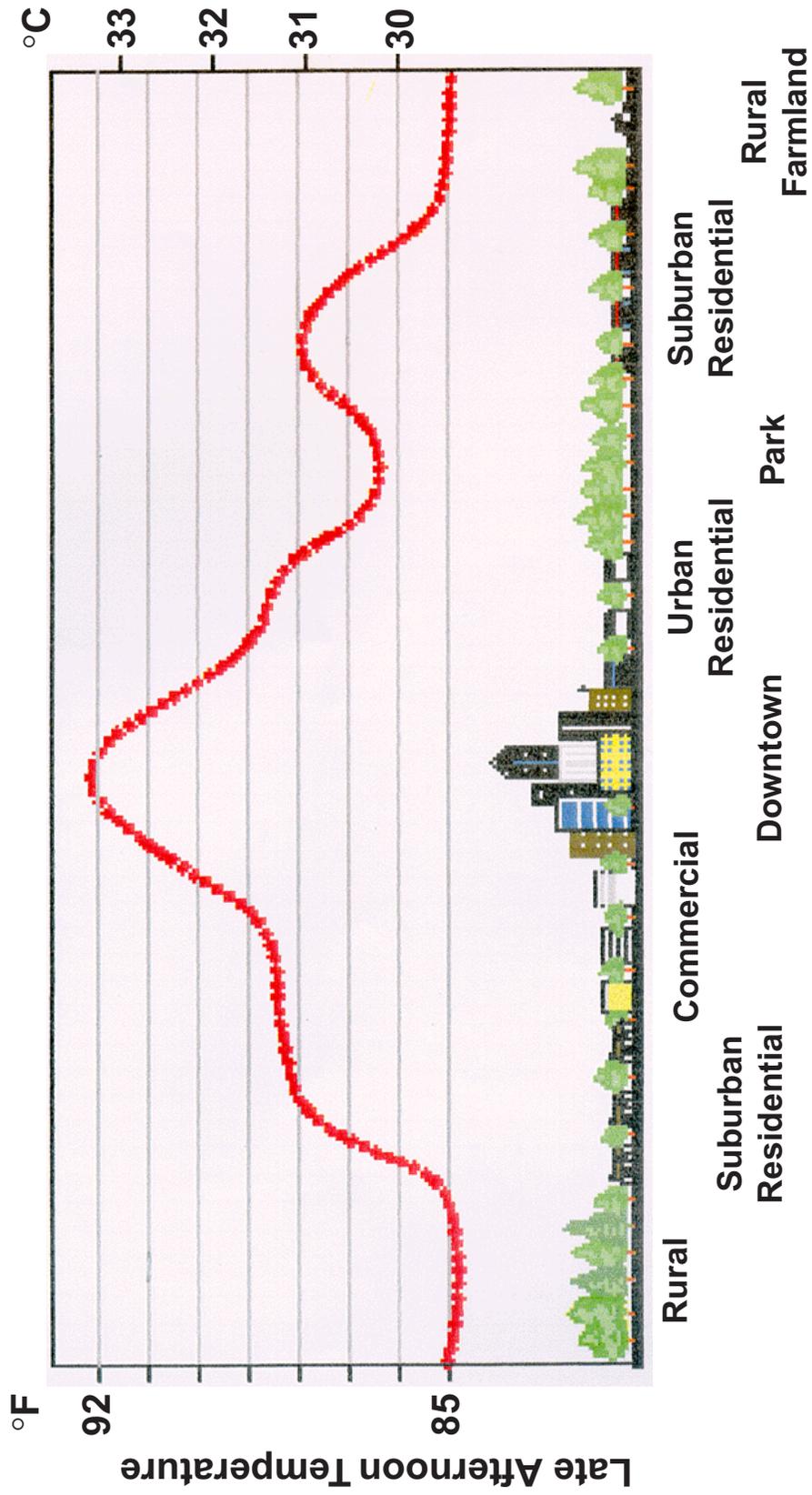
Figure 3: Land use 1997



Source: <http://svs.gsfc.nasa.gov/search/Keywords/Atlanta.html> — click on link for Atlanta Land Use.

| | | |
|--|---|---|
| ■ Dense Urban | ■ Forest | ■ Exposed |
| ■ Sparse Urban | ■ Water | ■ Cropland |

Figure 4: Sketch of an urban heat-island profile





Module 3, Investigation 3: Briefing

Why is the city hot?

Background

On a hot, sunny day if we wear dark clothes, we feel warm. Dark colors absorb more heat than light colors. We experience rising heated air when we walk across a paved parking lot on a sunny, summer day. The heat stored in the pavement warms the air and radiates to our bodies. On the other hand, when we sit under a tree, we feel cool. The moisture in trees and the shade they provide cools the area around them.

Temperatures are not uniform across a city. The amount of vegetation and colors of materials affect temperatures. Generally the denser and darker the building materials, the higher the temperatures. Masses of brick and asphalt absorb huge amounts of heat and then re-radiate the heat into the surrounding air. Color is a very important factor in heat gain. Dark colored materials such as slate or asphalt absorb more heat from the Sun than materials with lighter colors such as white roofing shingles or cement. Lighter colors reflect the rays of the Sun back into the atmosphere, and less heat is built up.

When heat builds up in a city, it creates a hot spot compared to the cooler countryside. This hot spot is called an urban heat island.

NASA scientists are studying temperatures in Atlanta, Georgia, because many trees were cut as the city grew. Tree removal contributes to forming urban heat islands. Trees were removed to make way for new houses, roads, parking lots, office buildings, and shopping centers. Scientists estimate that Atlanta's vegetation and tree cover decreased by 65 percent between 1973 and 1993. The area of tree loss equals 153,781 hectares (380,000 acres).

Objectives

In this investigation you will

- describe features on thermal images,
- identify change in land use and population changes leading to urban heat islands,
- explain how urban heat islands form,
- describe examples of environmental changes caused by urban heat islands, and
- offer ways to remedy some of the negative consequences of urban heat islands.

Procedures for the Investigation

Using Atlanta as a case study, you consider several aspects of urban expansion and its consequences for people and natural environments. To accomplish this you will examine land use maps and thermal images gathered by NASA. You will complete Logs distributed by your teacher.

References

NASA, Global Hydrology and Climate Center, Huntsville, Alabama <http://www.ghcc.msfc.nasa.gov>

NASA, Spacelink, an aeronautics and space resource for educators <http://spacelink.nasa.gov/>

Unit Converter: Online conversion of English and metric units <http://www.webcom.com/legacysy/convert2/convert2.html>

Excerpt from NASA research <http://www.ghcc.msfc.nasa.gov/overview/urban.html>

Images of Atlanta and information about heat islands
<http://science.msfc.nasa.gov/newhome/headlines/images/atlanta.jpg>
http://science.msfc.nasa.gov/newhome/essd/urban_heat/urban_heatisland_atl2.htm
<http://svs.gsfc.nasa.gov/imagewall/aaas.html>
<http://svs.gsfc.nasa.gov/imagewall/AAAS/atlanta.html>

Population of Atlanta
<http://demographia.com/dm-atlpor.htm>

Excerpt from *The Oregonian*, March 8, 2000
"A satellite's view of urban sprawl" by Richard L. Hill of *The Oregonian* staff



Module 3, Investigation 3: Log 1

Why is the city hot?

You have viewed the 1973 and 1987 land use maps showing changes in Atlanta resulting from urban expansion. More people moving into the city means that more trees have been removed and more roads built and buildings erected. This process is clearly revealed on the maps.

The 1987 map on page 3 is divided by lines G and 5 into four parts or quarters called quadrants. The set of lines placed over the map is called a grid. A number and letter correspond to each section or unit on the grid. This intersecting set of lines labeled with letters and numbers is called an alphanumeric grid.

1. Look at each quadrant and estimate the amount of land use change from 1973 to 1987.

Rank your choices in the following way:

- Noticeable change in 1-4 units is ranked low
- Noticeable change in 5-8 units is ranked moderate
- Noticeable change in 9 and above units is ranked high

The quarters or quadrants are:

Northeast Number of changed units _____ Rank _____

Northwest Number of changed units _____ Rank _____

Southwest Number of changed units _____ Rank _____

Southeast Number of changed units _____ Rank _____

2. Now identify the sections (units) in each quadrant where you think expansion of the built-up area continued to occur between 1987 and 1997. The numbers may vary from person to person.

Northeast Number of changed units _____

Northwest Number of changed units _____

Southwest Number of changed units _____

Southeast Number of changed units _____

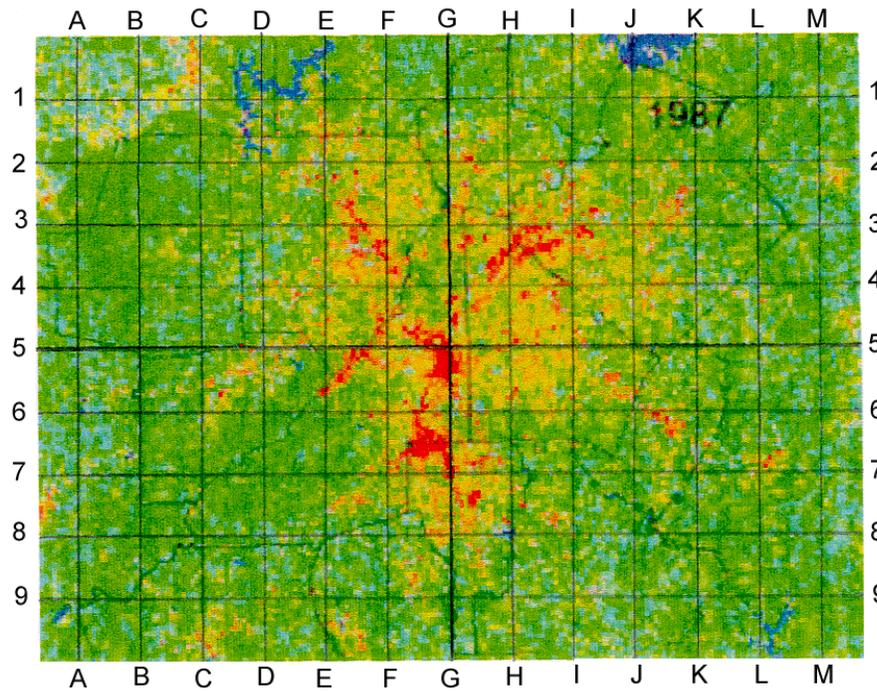
Why did you make those predictions?



Module 3, Investigation 3: Log 1

Why is the city hot?

Atlanta land use map 1987



| | | |
|--------------|--------|----------|
| Dense Urban | Forest | Exposed |
| Sparse Urban | Water | Cropland |



Module 3, Investigation 3: Log 1

Why is the city hot?

3. After your teacher shows you the 1997 land use map, make a comparison between the grid units you identified and where areas were actually built up. Is your set of grid units a good match for what happened? Explain.

4. Using a road atlas of the United States, do a visual comparison of the land use map and the highway system in Atlanta. What are your conclusions concerning where and why growth occurred?



Module 3, Investigation 3: Log 2

Why is the city hot?

You will use the day and night thermal images of Atlanta to identify features in the area. An alphanumeric grid is overlaid on each image to allow precise comparison of the two images. Use the day image first and identify the land uses in the following set of grid units.

- Set One: B6, B7, B8, and B9
- Set Two: E2 and I8
- Set Three: D5 and E5

Now use the night image and look at the same sets of units.

1. Which image allows you to make more precise identifications of land uses?

2. Why do temperature differences affect the way that land uses appear on the night image as compared to the day image?

3. Why do temperatures of roads remain warm at night and therefore very noticeable on the night image?

4. At the same time that the roads remain warm, what happens to areas nearby (for example in portions of grid units B6, B7, B8, B9)? What factors contribute to these cooler temperatures?

Concluding the Investigation

Using the following terms and symbols, create an equation that describes the relationships that lead to urban heat islands.

urban heat island
land use development
forests

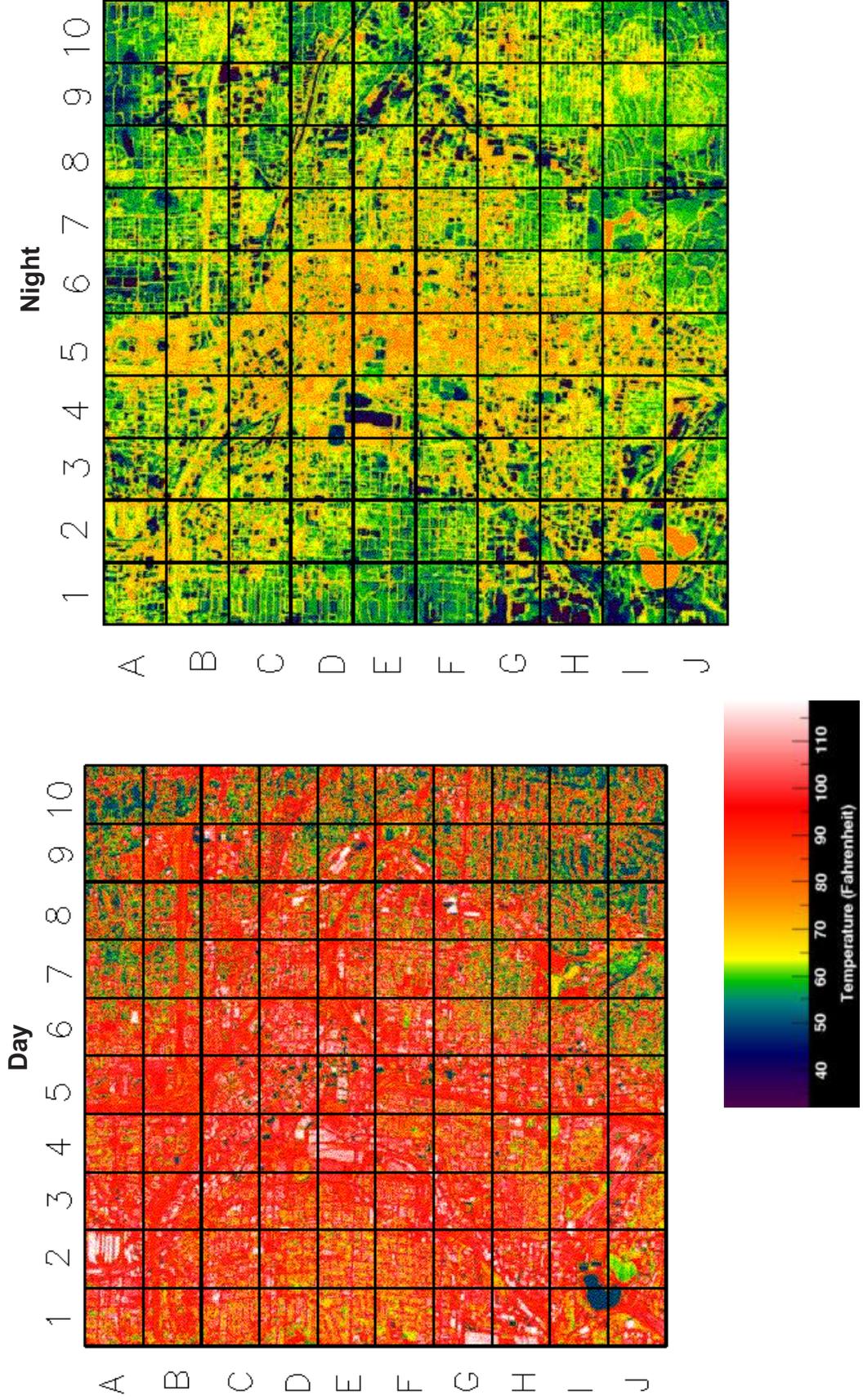
↑ (increase)
+ (plus)

= (equals)
↓ (decrease)



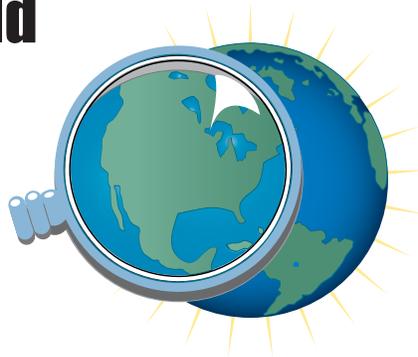
Module 3, Investigation 3: Figure 5

Atlanta, day and night





Where in the world are major environmental changes?



Investigation Overview

This investigation introduces students to the significant environmental changes occurring around the world. The investigation uses NASA satellite images of Brazil to illustrate deforestation as one type of environmental change. Students learn that satellite images provide useful information to interpret, understand, plan, and predict environmental changes.

Time required: Three or four 45-minute sessions

Material/Resources

Briefing and Logs 1, 2, and 3 (one of each per student)

Images of forests in Brazil

<http://www.bsrsi.msu.edu/rfrc/deforestation.html>

<http://edcwww.cr.usgs.gov/earthshots/slow/Rondonia/Rondonia>

Rainforest report card

<http://www.bsrsi.msu.edu/rfrc/facts.html>

Images of environmental change

<http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents>

World atlases

Outline maps of the world

Poster paper for display of group work

Content Preview

Deforestation is a significant environmental change in several regions of the world. Extensive tree removal often results in widespread habitat destruction. Large-scale reductions in vegetation may also lead to climate change. Deforestation in Rondonia, Brazil, as recorded by NASA imagery, provides a useful case study of a major environmental change.

Classroom Procedures

Beginning the Investigation

If you have completed an earlier investigation in this module, proceed directly to 3.

1. Have students develop a list of topics that NASA scientists study. Share the list with the class. Discuss the topics presented and have students identify which topics are local issues and which are global issues.

Geography Standards

Standard 4: Places and Regions

The physical and human characteristics of places

- Analyze the physical characteristics of places.

Standard 14: Environment and Society

How human actions modify the physical environment

- Analyze the environmental consequences of human changes of the physical environment.

Standard 15: Environment and Society

How physical systems affect human systems

- Analyze ways in which human systems develop in response to conditions in the physical environment.

Geography Skills

Skill Set 1: Ask Geographic Questions

- Identify geographic issues, define geographic problems, and pose geographic questions.

Skill Set 2: Acquire Geographic Information

- Use maps to collect and/or compile geographic information.

Skill Set 3: Organize Geographic Information

- Prepare various forms of maps as a means of organizing geographic information.

Skill Set 4: Analyze Geographic Information

- Interpret information from maps and satellite images.

Skill Set 5: Answer Geographic Questions

- Make generalizations and assess their validity.

2. Using the class discussion as a starting point, explain to students that NASA scientists study many topics and use photos and data gathered by airplanes as well as images and data gathered by satellites.
3. Distribute and have students read the **Briefing**.
4. Divide the class into groups of 3–4 students. Each group should have a recorder/reporter. Explain to students that some environmental changes negatively affect a large proportion of Earth's population, influence large areas of Earth, endure for a long time, and require the cooperation of many societies to solve or improve. If possible, have students explore the following web site on environmental change. See <<http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents>>.
5. Distribute **Log 1**. Ask students to identify, list, and discuss issues that they believe are major environmental changes. Responses may include: global warming, ozone depletion, removal of rainforests, water pollution, air pollution, loss of land to city expansion, rapid population growth, and resource depletion. Ask students to consider the advantages and disadvantages of the environmental changes to human populations in the affected areas. Ask them to refine their lists by evaluating each major environmental change with respect to the following four traits:
 - the portion of the world's population involved in the change,
 - the area of Earth influenced by the change,
 - the length of time that the effects endure, and
 - the number of countries required to solve or improve the conditions related to the change.
6. Group recorders report to the entire class the results of the small-group discussions, and the whole class compiles a comprehensive list of global/major environmental issues. These could be displayed for future reference.

Developing the Investigation

7. Ask each group of students to use world atlases and outline maps of the world to locate where each environmental change they identified is occurring. A change may be occurring in one or several

locations. For example, a major earthquake may occur at a single location, whereas a severe drought may affect many countries.

Using the atlases, students should give the latitude and longitude of the locations and a brief description of the physical characteristics of the regions where the environmental changes are occurring. Some changes will be more difficult to pinpoint than others. For example, warming of Earth's atmosphere may occur nearly everywhere rather than at just one or a few locations.

8. Distribute **Log 2**. Explain that human activities fulfill basic needs and have intended and unintended consequences on natural environments. For example, cutting portions of tropical rainforests to obtain valuable wood for export and clearing land for cattle grazing and settlements may have intended consequences of creating wealth for lumber companies and livestock owners and of offering places to live for migrating people. On the other hand, unintended consequences may include destroying species of wildlife dependent on the rainforest and altering climate in the region.

Concluding the Investigation

9. Distribute **Log 3**. Students have thought about environmental problems based on prior knowledge and class discussion, and they have mapped the problems they identified. Tropical rainforest destruction is a major environmental change. Images include selections from <<http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents>> depicting Rondonia, Brazil.

Background

To survive people depend on the physical environment. They adapt to it and modify it to suit their changing needs for things such as food, clothing, water, shelter, energy, and recreational facilities. In meeting their needs, they bring knowledge and technology to bear on physical systems. Clearing land for settlement, mining, and agriculture provides homes and livelihoods for some but alters physical systems and transforms human populations, wildlife, and vegetation. See *Geography for Life: National Geography Standards 1994*, p. 92.

Tropical Deforestation in Rondonia, Brazil

Approximately 30 percent (3,562,800 square kilometers) of the world's tropical forests are in Brazil. The estimated average deforestation rate from 1978 to 1988 was 15,000 square kilometers per year. Systematic cutting of forest vegetation starts along roads and then fans out to create the "feather" or "fishbone" pattern. The deforested land and urban areas appear in light blue; healthy vegetation appears red. See <<http://edcwww.cr.usgs.gov/earthshots/slow/Rondonia/Rondonia>>.

In Rondonia the forests are a resource for commercial logging. Valuable trees are cut and sold. Remaining trees may be burned along with other vegetation. Commercial cattle raising and farm settlements are other important reasons for deforestation in tropical rainforests. As the trees and other vegetation are removed, wildlife habitat is destroyed. Sometimes isolated forest parcels are left by deforestation, causing plants and animals to be cut off from the larger forest area. Large-scale forest removal threatens species and alters climate characteristics.

When land in Rondonia was opened for development by building a road through the forest, many settlers carved through the forest along regularly spaced, perpendicular roads from the main transportation artery. They created a fishbone pattern of deforestation. The fishbone pattern has the effect of dividing the remaining forest into many small parcels, providing very little undisturbed forest for wildlife in between. What would have happened if a different pattern of clearing had been used such as a hub-and-spoke pattern? If a hub and spoke were used, the undisturbed areas would have been larger and wildlife would have been less threatened by development. If sections were designated as preserves on which no development could occur, the possibility of species preservation would be even greater.

The actual rate of deforestation is difficult to determine and has been the focus of NASA-funded study for many years. NASA projects to investigate the deforestation of tropical forests are conducted by analyzing satellite images to determine the area of forest that has been cleared. <<http://www.bsrsi.msu.edu/rfrc/deforestation.html>>

Evaluation

Log 1

Students will add issues to the Environmental Changes Checklist that they identify as major environmental changes. The issues on the checklist will vary among students. The following is a sample of some possible environmental changes.

Environmental Changes

| Changes | A | | B | | C | | D | |
|-----------------------------------|---|---|---|---|---|---|---|---|
| | y | n | y | n | y | n | y | n |
| Air pollution from burning fuels | ● | | ● | | ● | | ● | |
| Thinning of ozone layer | ● | | ● | | ● | | ● | |
| Oil spills in the ocean | | ● | | ● | ● | | ● | |
| Cutting down tropical rainforests | ● | | ● | | ● | | ● | |
| Rapid population growth on Earth | ● | | ● | | ● | | ● | |

Log 2

Students develop their own answers to questions concerning basic human material needs. For example in Question 1, "What are the basic material needs that all people have?" Students could answer, "Food, shelter, and water" or "Hamburgers, french fries, and milkshakes." Any answers that they provide should then be used to complete the remaining questions. Students should not be expected to have identical answers.

Log 3

1. In the 1992 image, there are more settlements than in 1975, as shown by the increase in blue areas. Light red streaks are apparent in the 1992 image but not in the 1975 image, indicating deforestation.
2. The pattern of deforestation in the 1992 image is in long, narrow lines that stay about the same distance apart all along the length of the lines. This is a fishbone pattern.
3. Valuable species of trees are cut and sold by commercial loggers. The remaining trees and vegetation are often burned, clearing land for growing crops, raising livestock, and building houses and stores.
4. Animals that need large expanses of forest to live may be at a disadvantage as the forest is broken up into long, parallel strips. They may be forced to remaining parts of the forest to search for food and shelter, or they may become endangered or extinct.
5. One pattern that might preserve large areas of forest is a hub and spoke pattern similar to a wagon wheel. A central settlement with roads running out in different directions might preserve large areas of land for wildlife that would remain connected to the whole forest. Students may suggest other patterns.
6. The pattern suggested in Question 5 might be better than the pattern in the 1992 image because it would preserve large areas of forest while still allowing new settlement and tree cutting.
7. Deforestation in Rondonia affects other places. For example, trees are sold to make products sold in other locations. People who settle in the newly cleared forest come from other places. Also, extensive deforestation and burning causes changes in atmospheric gases such as carbon dioxide. Loss of plant species that may have had medicinal benefits also occurs.
8. People might make products from materials in the forest without cutting the trees or they might grow crops that require less tree removal.

Concluding Activity

Sample ideas for short essay topics:

Advantages: More space for humans to live, income from farming or mining cleared land, income from selling valuable trees

Disadvantages: Species of plants and animals may decline or become extinct, harmful changes might occur in atmospheric gases

Resources

Images of Rondonia, Brazil
<http://edcwww.cr.usgs.gov/earthshots/slow/Rondonia/Rondonia>

Images of environmental change
<http://edcwwwcr.usgs.gov/earthshots/slow/tableofcontents>

Images of forest area in Brazil
<http://www.bsrsi.msu.edu/rfrc/deforestation.html>

Rainforest report card (locator map)
<http://www.bsrsi.msu.edu/rfrc/geography.html>



Module 3, Investigation 4: Briefing

Where in the world are major environmental changes?

Background

Many environmental changes are interconnected on a global scale. For example diseases that originate in one place may threaten populations in other places as people migrate from region to region. Also, unusual climate and weather conditions may destroy crops in one country and create bumper crops in another country. Serious food shortages may occur in one place and surpluses in another. Moving food over long distances may be required to avoid starvation and malnutrition. NASA scientists are interested in monitoring environmental changes on Earth's surface so that their consequences can be understood and predicted. Environmental changes often affect human well-being.

Human activities on Earth's surface have intended and unintended consequences. For example, cutting portions of tropical rainforests to obtain valuable wood for export to other countries, clearing land for cattle grazing, and settlements may result in creating wealth for lumber companies and livestock owners and in providing places to live for migrating people. Unintended consequences may include destroying species of wildlife dependent on the rainforest and altering Earth's climate. Unintended consequences may not be understood in time to repair the negative environmental changes.

In this investigation, you consider what makes up a major environmental change and then look at deforestation as an example. Deforestation is a major research topic for NASA scientists.

Objectives

In this investigation you will

- describe several major environmental changes,
- locate places in the world where major environmental changes are occurring,
- give reasons why an environmental change may be classified major,
- describe issues related to deforestation in a tropical region,
- offer ways to remedy some of the negative consequences of deforestation,
- describe features on thermal images, and
- explain why NASA scientists study environmental changes.

Procedures for the Investigation

You identify and classify examples of major environmental changes on Earth's surface. You use atlases to locate places where the environmental changes are occurring and describe the features of those places. You examine remotely sensed images of Brazil's forests to identify patterns of deforestation and speculate about what caused the patterns and how they might be changed.



Module 3, Investigation 4: Log 1

Where in the world are major environmental changes?

For this investigation, your class will be divided into groups to consider different types of environmental changes and issues. Each group should have a recorder/reporter who will share group findings with the entire class.

Many environmental changes negatively affect a large proportion of Earth’s human population, influence large areas of Earth’s surface, endure for a long time, and require the cooperation of many societies to solve or improve. Working in your groups, identify and list issues that you believe are major environmental changes. Once you have identified your list, enter them below and compare each environmental change on the list against the following traits. Does each environmental change have the four traits? Air pollution from burning fuels is given as an example below.

Traits

- a. A significant portion of the world’s population is involved in the change.
- b. Large areas of Earth are influenced by the change.
- c. The problem has effects that endure a long time.
- d. The cooperation of several countries may be required to solve or improve the conditions related to change.

Group recorders report to the class, and differences and similarities are discussed.

Environmental Changes Checklist

| Changes | Trait a | | Trait b | | Trait c | | Trait d | |
|---------------|---------|----|---------|----|---------|----|---------|----|
| | Yes | No | Yes | No | Yes | No | Yes | No |
| Air pollution | ● | | ● | | ● | | ● | |
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Module 3, Investigation 4: Log 2

Where in the world are major environmental changes?

Think about and answer these general questions.

1. What are the basic material needs that all people have?

2. What are the resources that people use to fulfill basic needs?

3. How do people get these resources?

4. How does getting needed resources affect the natural environment? Provide examples.

5. How do the resource choices of one group affect other people? Provide examples.



Module 3, Investigation 4: Log 3

Where in the world are major environmental changes?

1. Describe two differences that are observed between the 1975 and 1992 images.

1)

2)

2. Describe the pattern of deforestation that you see on the 1992 image.

3. What human activities created the pattern?

4. If animal populations need large expanses of natural forest to live and reproduce, what would be the effects of the change in land use patterns on animal populations?

5. Using the image as a model, on a separate sheet of paper, do a sketch map of a pattern that you think would be better to preserve wildlife habitat and still allow some settlement activity in the region. Is there a better way to develop the forest and still provide for the needs of animals?



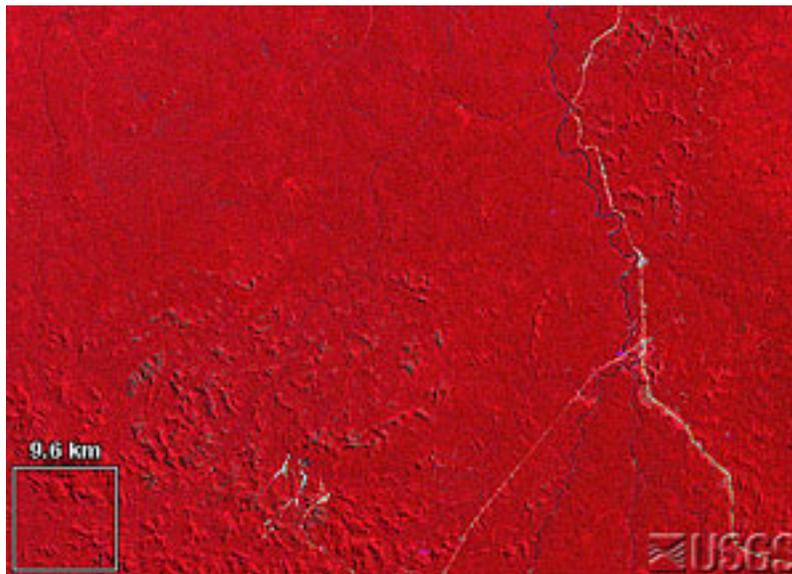
Module 3, Investigation 4: Log 3

Where in the world are major environmental changes?

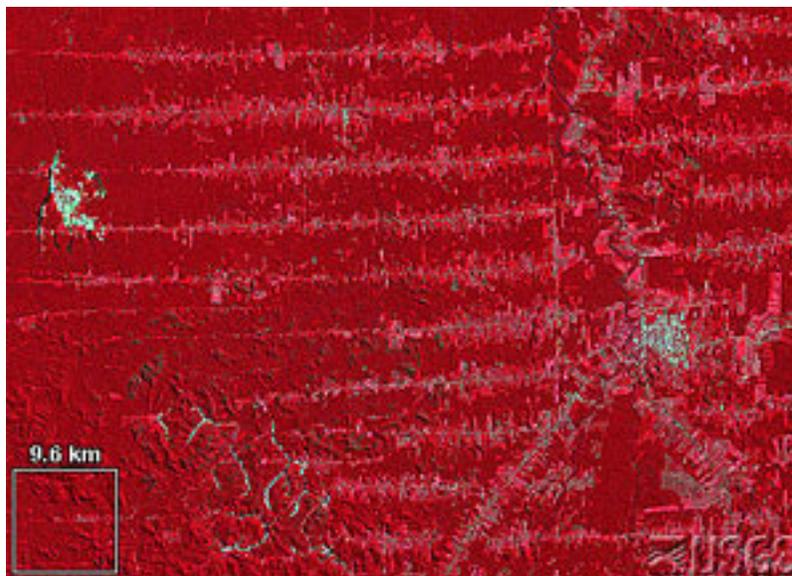
Dark red indicates forested areas. Light red indicates deforested areas. Light blue shows settlements.

Notice that in the 1975 image there is a line of light red and some small blue dots. These represent a road through the forest and some small settlements. Little deforestation had taken place in this area of Rondonia. Now examine the 1975 and 1992 satellite images of Rondonia, Brazil. Both images are from Landsat.

1975



1992



Source: <http://edcwww.cr.usgs.gov/earthshots/slow/Rondonia/Rondonia>



Module 3, Investigation 4: Log 3

Where in the world are major environmental changes?

6. Why do you think your proposed pattern would be better than the current pattern on the 1992 image?

7. Does deforestation in Rondonia affect other places? How?

8. Are there some other ways that basic needs might be met that would have less impact on the environment?

Concluding the Activity

Using what you have learned in this investigation, develop a short essay on the following question:
What are the advantages and disadvantages for people when forests are cut down?